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Revision 0

Evaluation of Residual Mercury at the CFA-04 (CFA-674) Pond

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ABSTRACT

This white paper was written concurrently with the remedial design/remedial action work plan for the Central Facilities (CFA)-04 pond mercury contaminated soils to evaluate residual mercury contamination that may remain following excavation of the CFA-04 pond. The selected remedy for the pond is defined in the *Final Comprehensive Record of Decision for Central Facilities Area Operable Unit 4-13*.

Based on preremediation characterization sampling performed in 2002 (DOE 2002a), it is apparent that mercury contamination is present at levels above the final remediation goal (8.4 m/kg) in soil located in fractures in the basalt layer in low areas of the CFA-04 pond. The presence of this mercury is due to the disposal of effluent containing mercury during the operation of the CFA-674.

It will be extremely difficult to remove residual mercury-contaminated soil that may be present within small fractures in the basalt. However, it is also expensive to maintain institutional controls over a site. This paper evaluates an approach to calculating an overall mercury concentration in the remaining soil assuming a conservative soil to basalt ratio of 10%. The approach was used to determine the average concentration of mercury in selected areas based on the 2002 preremediation sampling. The average concentration for mercury from residual contamination was calculated to be 2.9 mg/kg. This concentration is below the final remediation goal of 8.4 mg/kg.

During the remedial activities at the CFA-04 pond, it will be important to validate the soil to basalt percentage assumed as well as recharacterize the residual mercury concentration. If the soil to basalt ratio is greater than 10% or if the concentration in the soil within the basalt fractures is greater than the preremediation characterization sampling evaluated in this white paper then the average concentration of the residual soil made in this assessment will need to be reevaluated.

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ACRONYMS

CEL	Chemical Engineering Laboratory
CFA	Central Facilities Area
DOE	Department of Energy
DOE-ID	Department of Energy, Idaho Operations Office
FRG	final remediation goal
Hg	mercury
INEEL	Idaho National Engineering and Environmental Laboratory
OU	operable unit
RWMC	Radioactive Waste Management Complex

Evaluation of the Residual Mercury at the CFA-04 (CFA-674) Pond

1. INTRODUCTION

The Central Facility Area (CFA)-04 dry pond was formerly used for disposal of wastes from operations at CFA-674 (DOE-ID 2002a). The pond, located southeast of CFA-674, is a shallow depression approximately 150 ft (46 m) wide by 495 ft (151 m) long by 9 ft (2.7 m) deep (Figure 1). The pond is scheduled for final remediation of mercury-contaminated soil during the summer of 2003. Normally, it is expected that although some mercury contamination would remain after remediation, the average concentration would be below the final remediation goal (FRG). This is generally verified by postremediation sampling. However, levels of concern may remain in some areas of the pond, where the basalt soil interface has mercury concentrations greater than the FRG. In these areas contaminated soil may be present within the small fractures in the basalt. Soil in these fractures will be extremely difficult to remove. Preremediation characterization of these areas during 2002 (DOE-ID 2002b) indicates that it is likely that concentrations of mercury in the soil will be significantly above the FRG of 8.4 mg/kg. There is some concern that the remaining mercury within the fractures in the basalt would constitute risk to either human health or the environment and therefore require that institutional controls be maintained at this site. This white paper will present an approach to estimate the amount of contaminated soil within the basalt fractures, and to use this value to calculate the average mass and concentration of the mercury remaining in the soil at the CFA-04 pond for comparison to the FRG. This approach is applied to the concentrations detected during the 2002 preremediation sampling.

Section 2 discusses the background and history of the site and the nature and extent of the contamination. Section 3 discusses the percentage of soil to basalt that may remain following remedial efforts. Section 4 presents the method used to calculate the mass of residual mercury remaining after remediation. This mass is then used to calculate an average concentration in the residual soil for comparison to the FRG. Section 5 discusses the human health risk assessment methodology for developing the FRG and how the approach used is consistent with protection of human receptors. Section 6 discusses the ecological risk assessment methodology for developing the FRG and how the approach used is consistent with the protection of ecological receptors. Section 7 presents the results and conclusions of this white paper.

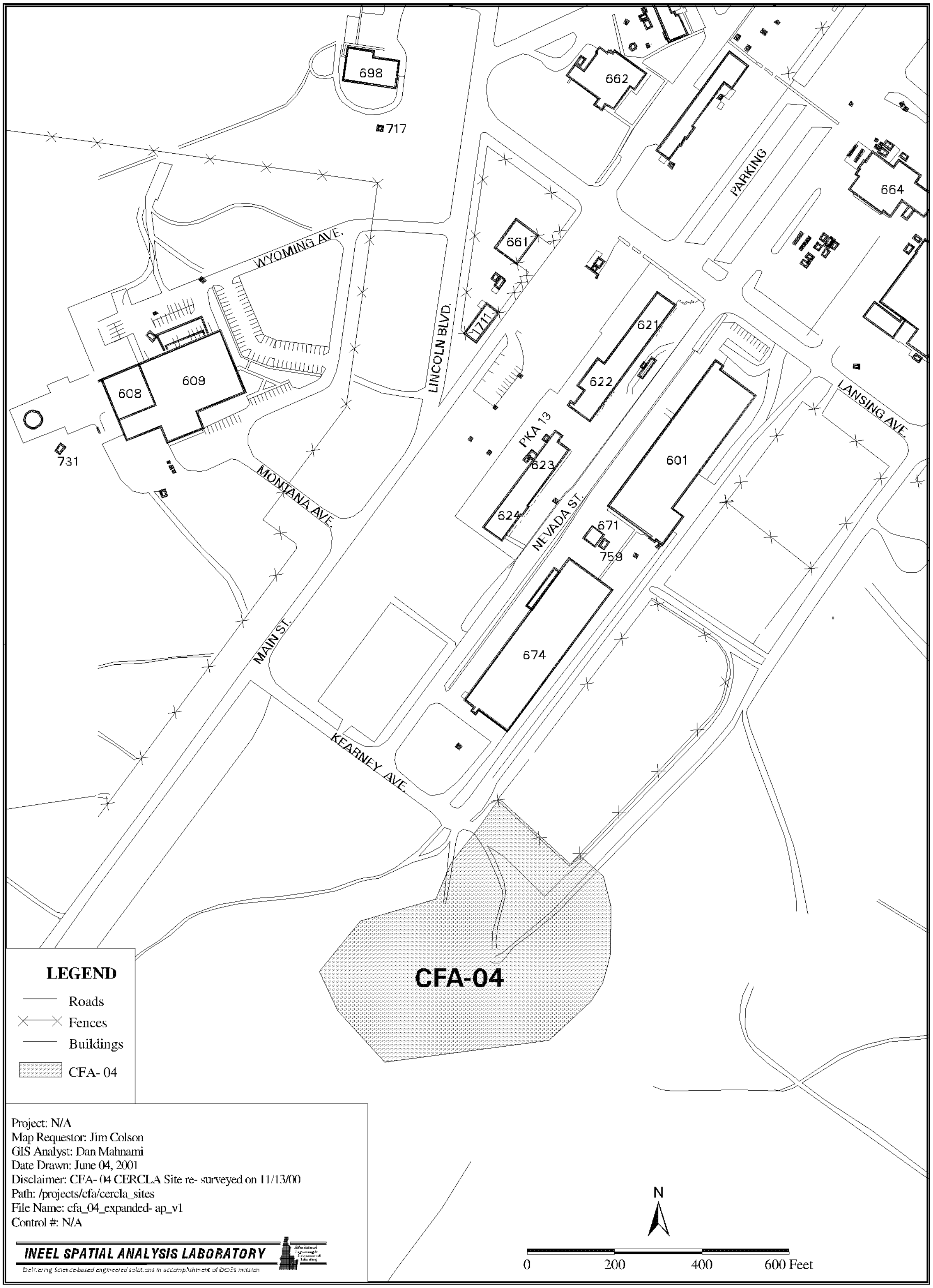

Figure 1. Location of CFA-04 pond.

2. BACKGROUND AND HISTORY OF THE CFA-04 POND

The CFA-04 pond is a shallow, unlined surface depression used for disposal of wastes from operations at CFA-674 (Figure 1). Building CFA-674 was built in 1952 to support activities associated with the development and testing of a nuclear waste calcining process on simulated (no fuel) nuclear fuel rods. The Chemical Engineering Laboratory (CEL) in the building was operational from 1953 to 1969 and disposed of waste to the CFA-04 pond during this time period.

Three pilot-scale calciners were housed in the CEL between 1953 and 1965. The calcination process involved spraying a nitric acid solution of metal salts on a heated fluidized bed where the salts were converted to oxides such as $Hg(OH)_2$. The calcine product also contains 4 to 16% nitrate (DOE, 1962). Remaining nitrates in the end solution were vaporized and released in off-gases or captured in the liquid effluent by the scrubber and condenser systems used to treat the off-gases. Mercury was used in the CEL experiments as a catalyst in the dissolution of simulated aluminum fuel cladding.

The two primary waste streams containing mercury discharged to the pond from the CEL included mercury-contaminated calcine (that contained low-level radioactive wastes) and the liquid effluent from the laboratory experiments. In addition, there is approximately 382 m^3 (500 yd^3) of rubble consisting of asphalt and asbestos roofing materials, reinforced concrete, and construction and demolition debris that is not considered further in this evaluation.

2.1 Waste Streams

Process information and reports indicate that approximately 70 m^3 (93.6 cubic yards) of simulated calcine was generated from this laboratory from 1953 to 1965. As much as 450 kg of Hg (probably HgO) contaminated about 60% of the calcine. The calcine was often in a light granular form, but could have a fine to almost rock-like texture. Solid calcine was disposed in areas in and around the CFA-674 pond. Some of these areas had exposed calcine at the land surface while others were covered with gravel backfill. The surface calcine contributed to wind dispersal of mercury to surficial soils in the pond area. Bottles containing calcine, generated as process samples, were also present and were covered with backfill after disposal.

Liquid effluents discharged to the CFA-04 pond from CEL between 1953 and 1969 may have included effluents generated during the liquid-liquid extraction of uranium (INEEL 1996). The volume of contaminated effluent discharged to the pond from CEL operations could not be estimated (INEEL 1996). Some of the mercuric nitrate scrub solutions from the calcine test plants are known to have been disposed of at the Radioactive Waste Management Complex (RWMC) acid pit (LITCO 1996). Mercury vapors were detected in the discharge area and the pond bottom in areas where simulated calcine was not present and is believed to be from the CEL effluent discharges (INEEL 1996). Based on the concentrations of mercury found in the soils of the inlet and low areas of the pond (Table 1), it can be assumed that at least part of the effluent from the pilot-scale calcinors was discharged to the pond.

2.2 Nature and Extent

Although the 1994 removal action had reduced the amount of simulated calcine, contamination from the effluent residual calcine still remains in the pond. This site was identified for remediation in the Record of Decision (ROD) for Central Facilities Area Operable Unit (OU) 4-13 (DOE-ID 2000b). Pre-remediation sampling was performed in 2002. The Waste Area Group (WAG) 4 Remedial Design/Remedial Action (RD/RA) Work Plan, CFA-04 Pond Mercury Contaminated Soils, OU 4-13 (DOE-ID 2002b), states that samples had been collected to define the areal and vertical extent of mercury contamination in the CFA-04 pond (refer to Appendix A of the field sampling plan [DOE-ID 2002a]). Adequate information was available that detailed the contamination levels in the pond surficial soils, much of the bermed area, and the surficial soils in the windblown area. However, data gaps still existed in the definition of the vertical extent of contamination in the pond area and the bermed area along the southern edges of the pond. To aid in the excavation of the soils during the remedial action in an effort to minimize the volume of contaminated soils requiring disposal, additional sampling for mercury was performed. The results of this sampling are presented in Table 1. The sampling locations associated with these locations are presented in Figure 2, which also shows the depressions at the site. Area 5 is the inlet of the pond with Areas 6, 7, and 8 consisting of some of the lowest areas of the pond.

Table 1. Summary of mercury concentrations in mg/kg.[a]

	Sampling Interval (ft)								
Area	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
1	1.9	0.14	0.05	0.08	0.06	0.11	—	—	—
2	8.8/2.5	2.4	0.90	0.84	0.24	—	—	—	—
3	2.9	2.7	0.21	0.08	0.05	0.04	0.05	0.06	—
4	2.1	0.55	0.08/0.12	0.02	0.06	0.04	0.07	0.02	—
5	63.0/56.4	—	—	—	—	—	—	—	—
6	57.3	75.8	82.8	54.7	42.7	47.0	—	—	—
7	85.3	45.5	68.4/67.7	118	44.2	—	—	—	—
8	90.3	60.6	60.6	126	—	—	—	—	—
9	4.5	1.7	0.21	0.13	0.09	0.06	—	—	—
10	4.5	2.5/0.97	—	—	—	—	—	—	—
11	5.2	15.0	19.2	2.2	1.0	2.2	—	—	—
12	9.2	13.3	2.2	1.9	1.3	1.9	2.5	1.1	1.7
13	22.4/34.4	10.4	2.0	0.76	0.08	0.07	0.04	0.05	—
14	41.4	40.0	5.1	2.7	12.1	1.3	2.2	0.03	—
15	0.18	0.09	0.07	0.29	1.8	0.05	0.05	—	—

a. From Appendix D, Table 6-1 (DOE-ID 2002b).

Note: For those intervals within an area where two mercury concentrations are provided, one value is for the sample and the other is for a field duplicate.

It was determined that three likely species of mercury (Hg^{o}, HgO, and $Hg(NO_3)_2$) are present from the simulated calcine disposed of in the pond (INEEL 1996). Based upon a consideration of the process chemistry most of the mercury is considered to be in the mercuric oxide form. Mercuric oxide is highly adsorptive, and is not believed to migrate extensively. This is evident in the preremediation sampling (Table 1) where many of the areas within the site have elevated levels of mercury in the soil; however, not to depth. This includes Areas 2, 11, 12, 13, and 14.

Liquid effluents discharged to the CFA-04 pond from CEL between 1953 to 1969 may have included mercuric nitrate scrub solutions from the calcine test plants (INEEL 1996). Limited records exist concerning the exact amount of effluent that was disposed of to the pond, and there was some concern regarding the depth to which the mercury (from the effluent) was driven into the subsurface soil. Sampling in 2002 indicated that the mercury might have been driven some distance into the soil in low areas where ponding could occur. These include the inlet and associated depressions in the pond including areas 5, 6, 7, and 8 (Figure 2 and Table 1). In these areas, effluent wastes released may have traveled downward sporadically through narrow fractured pathways.

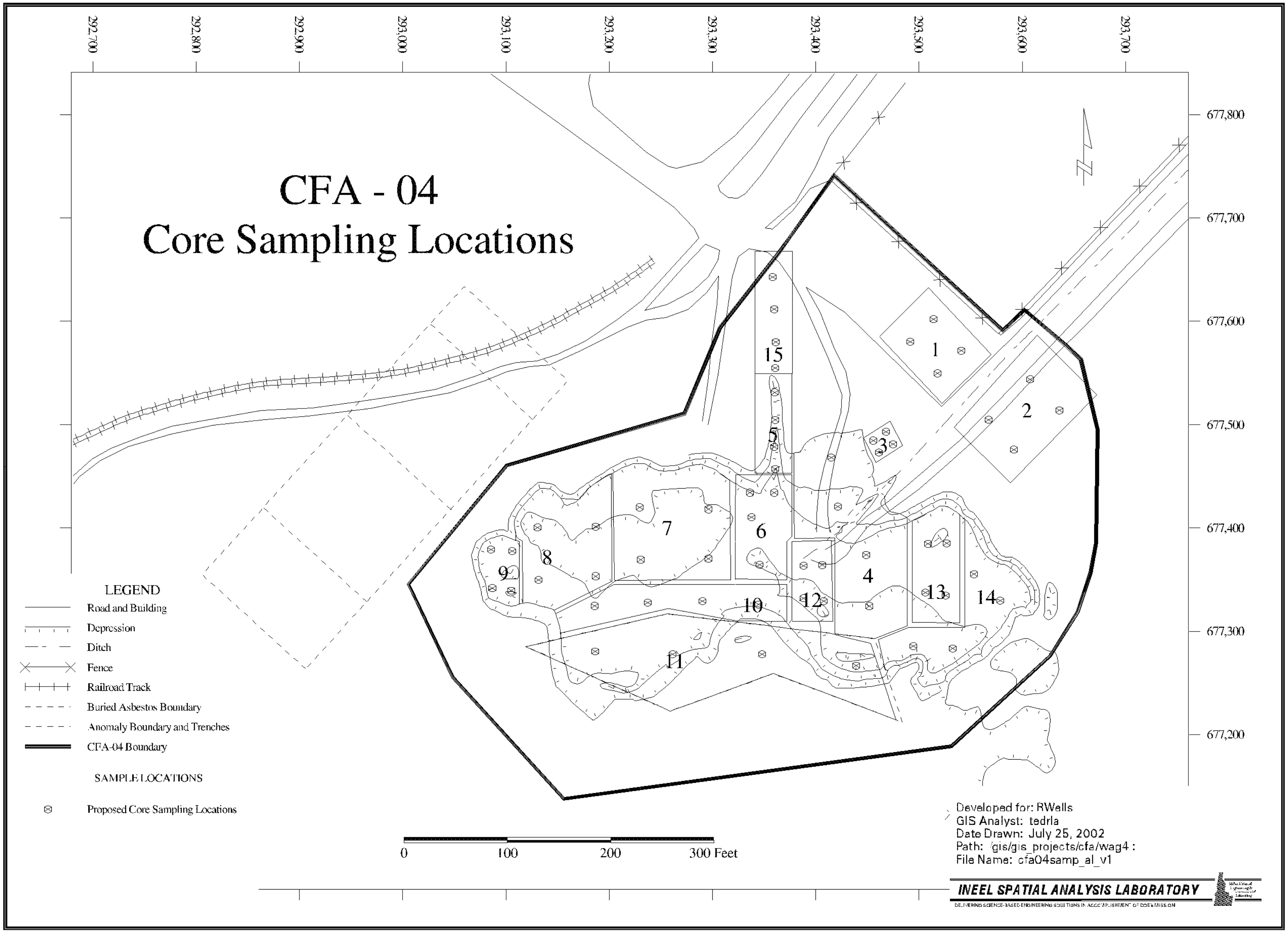

Figure 2. Sampling locations at the CFA-04 pond (DOE-ID 2002b).

As shown in Figure 2, the low points in the pond that contain the highest concentration of mercury from waste effluent are Areas 5, 6, 7, and 8. A summary of the mercury concentrations presented by the sampling interval in Table 1, indicate that mercury concentrations at the basalt to soil interface in these same areas do not decrease below the FRG level. Therefore, it is apparent that mercuric compounds from historical processes may have migrated into the subsoil in areas 5, 6, 7, and 8. However, it is expected that most of the mercury remaining will have been bound up by the soil. Under natural condition, most of the Hg^{2+} in the soil is either bound in the soil minerals or adsorbed onto organic or inorganic solids, with only a very small portion present in the soil solution (Steinnes 1995). This assumption has been verified by the downgradient wells sampling results that indicate no detections of mercury are present (DOE-ID 2002c). Nitrate has been seen at CFA-MON-002 just south of the CFA-04 pond. However, a nitrogen isotope study performed in 1999 indicates that the most likely source of nitrate contamination is sewage effluent (INEEL 2002a).

3. DETERMINING THE PERCENTAGE OF SOIL TO BASALT

It is well known that basalt will fracture and crack extensively along its surface as it cools. At CFA-04, it is possible that underlying the pond, soil contained in the fractures in the basalt has become contaminated with mercury from effluent disposal during CFA-674 activities. In the remediation of a contaminated site with fractured basalt it is very difficult and expensive to remove all contamination. To evaluate the possible residual contamination remaining in the soil within the fractured basalt, the percentage of soil to basalt must be estimated.

An evaluation of the literature, found at the INEEL, was conducted to determine physical characteristics of the basalt layer typically found beneath sites nearest to the CFA-04 pond. Specific information regarding the physical characteristics of the fractured basalt lying beneath the CFA-04 pond is lacking. A potential source of information would be well core samples and/or boreholes that could possibly provide the amounts of sediment in the fractured areas of the basalt layers in this area. However, these data were not available. Most other studies at the INEEL are generally more focused on evaluating the fractures as a pathway to the underlying sediments or groundwater. Furthermore, it was suggested that "point" measurements in a fractured system could not reveal physical characteristics across a larger scale in a complex system.

The Snake River Plain is primarily composed of fractured basalt flow units, interlayered with sedimentary deposits (Welhan and Reed 1997). Basalt units are composed of a number of basalt flows arising from the same eruption event. Individual basalt flows generally consist of multiple lobes that are elongated in one direction, giving them a finger-like or lenticular structure. Typical lobe dimensions are 3–12 m thick and 20–60 m wide (Sorenson et al 1996). These basalt flows are typically highly fractured or rubblized at the flow margins.

To quantify the percentage of soil or sediment in the fracture basalt in the CFA-04 pond, a study conducted by Faybishenko et al (2000) describing the lithology and fracture pattern at the Box Canyon Site, located in the Eastern Snake River Plain east of the INEEL near the Big Lost River, was reviewed. In this study it was found that spacing between fractures for several basalt flows, likely of the same eruption, was markedly similar and exhibits an increase in spacing with depth in the upper two thirds of the flow thickness. At the upper surface of the basalt flow the spacing between fractures was found to be as low as 0.3 m (1 ft). In a separate study conducted by Knutson et al (1992) at the RWMC (located five miles southwest of CFA-04), the average density of fractures in the upper portions of basalt flows was similarly found to be one to two fractures per ft. Knutson et al (1992) showed that shrinkage resulted in fractures perpendicular to the surface of the flow and relief joints or fractures were found parallel to and near the top of the flow. An example of fractures in a basalt layer from the Faybishenko et al (2000) paper is shown in Figure 3, illustrating that the top two thirds of the basalt flow contains the most fractures and cracks.

For this evaluation, based on the Faybishenko et al (2000) and Knutson et al (1992) studies, the average density of fractures in the upper portions of basalt flow at the CFA-04 pond was assumed to be once every foot. Assume a 120 in. (10 ft) × 120 in. (10 ft) × 120 in. (10 ft) block of basalt. The total area of this block is 1,728,000 cu in. (1000 cu ft). If it is assumed that fractures occur every 12 inches (there will be 10 within the block) and that each fracture is 1 in. (.08 ft) thick and 120 in. (10 ft) deep and 120 in. (10 ft) long, then the total area of the fractures is 144,000 cu. in. (83.3 cu ft). Given these assumptions the fractures are approximately 8.3% of the total area. As shown in Figure 3, the area of the fractures is less at increased depth. Therefore, for this assessment, it will be conservatively assumed that 10% of the basalt layers within the pond are fractures containing sediment that cannot be remediated.

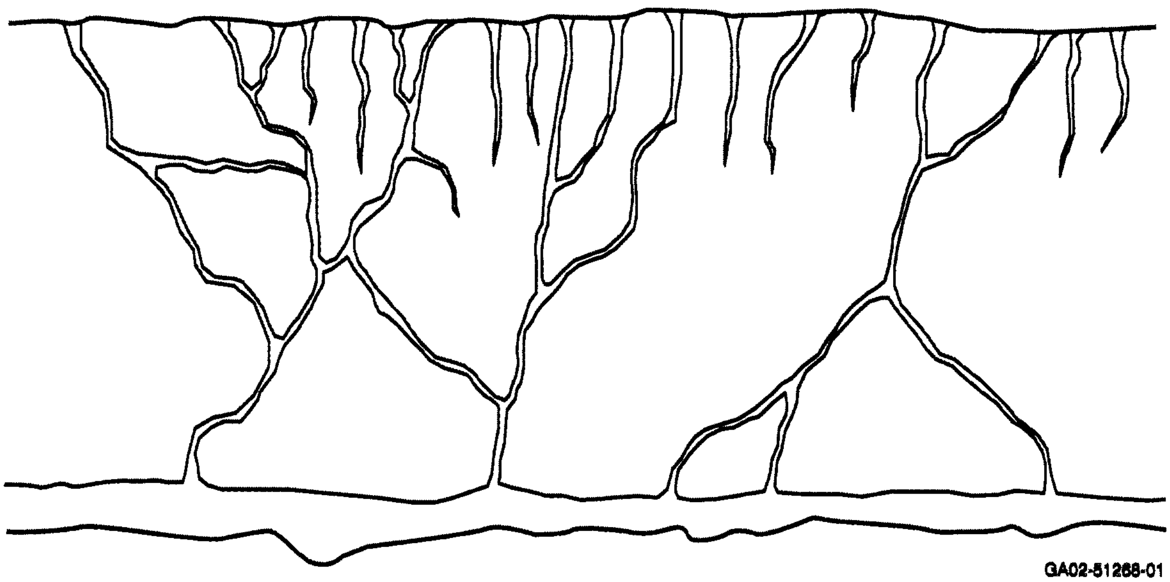

Figure 3. An example of fractures in basalt flow (after Faybishenko et al. 2000).

4. CALCULATION OF AN AVERAGE SOIL CONCENTRATION

An average soil concentration is used in the evaluation of a contaminated site in assessing both human and ecological risk. For the human health resident intrusional scenario a basement of 10 ft is assumed and the 95% upper confidence level (UCL) of the mean is calculated from all samples collected. The ecological risk assessment uses similar assumptions in the assessment of risk to ecological receptors. CFA-04 is a dry pond with a 9-ft deep depression. Remediation activities will only replace any soil that was removed and will not fill the depression. To calculate an average soil concentration, through a 10-ft depth, it was conservatively assumed that the soil surface area of the pond is level. The volume of contaminated soil to be removed and replaced at the CFA-04 pond is presented in the RD/RA work plan (DOE-ID 2002b) by areas. Table 2 summarizes the excavation depth to basalt, and volumes and masses of soil to be removed by areas where the basalt is within the 10 ft range from the surface. This includes Areas 5, 6, 6A, 7, 7A, and 8.

Table 2. Excavation depth and volume of soil in basalt fractures for selected areas.

	Excavation Depth (ft)	Area (ft^2)	Volume to 10 ft Depth (cm^3)	Volume of Soil Removed/ Replaced Over the Basalt (cm^3)	Volume of Basalt (cm^3)	Volume of Soil Within the Fractures (cm^3)
Area 5	1	3.78E+03	1.07E+09	1.07E+08	9.62E+08	9.62E+08
Area 6[b]	6	6.02E+03	1.70E+09	1.02E+09	6.82E+08	6.82E+08
Area 7[b]	5	1.31E+04	3.70E+09	1.85E+09	1.85E+09	1.85E+08
Area 8	4	1.01E+04	2.85E+09	1.14E+09	1.71E+09	1.71E+08

a. Conversion from cubic feet to cubic centimeter is done by multiplying by 28,316.85.

b. Areas 6A and 7A are included within the volumes for Area 6 and Area 7, respectively.

A volume was calculated for each of these areas. Of this total volume, the volume of the basalt within the area was calculated by subtracting the total volume of each area. The volume of contaminated soil was assumed to be 10% of the basalt layer located within the 10 ft zone. These volumes were used to determine the mass of contaminated soil remaining in the basalt fractures following remediation efforts and the mass of clean soil over the basalt. Both these masses were calculated by multiplying the volume by the standard soil density of 1.5 g/cm^3 for INEEL soil.

The mass of the residual mercury at each area was determined by multiplying the mass of the residual soil in kilograms by the mercury soil concentration at the basalt soil interface taken during the 2002 pre-remediation sampling (Table 1). The average concentration of mercury in the soil for each area was then calculated by dividing the total mass of mercury by the total mass of soil (both clean and residual contaminated). The results of these calculations are listed in Table 3.

An average residual mercury concentration in soil was calculated for selected areas of the CFA-04 pond (Areas 5, 6, 6A, 7, 7A, and 8) as shown in Table 3. For two areas the average concentration is greater than the FRG. When the total mass of mercury is divided by the mass of the clean soil and the mass of the contaminated soil, the average soil concentration of mercury for these selected areas is 8.27 mg/kg. This is slightly less than the FRG of 8.4 mg/kg. However, as the FRG was calculated using the total area of the pond, the average concentration of mercury is acceptable.

Table 3. Masses and concentrations used to estimate the average concentration of mercury in the soil.

	Concentration of Mercury at the Basalt Soil Interface (mg/kg)	Mass of Clean Soil (kg)	Mass of Contaminated Soil Within the Fractures (kg)	Mass of Mercury (mg)	Average Concentration of Mercury in Soil (mg/kg)
Area 5	56.4	1.60E+05	1.44E+05	8.14E+06	2.67E+01
Area 6[a]	47.0	1.53E+06	1.02E+05	4.80E+06	2.94E+00
Area 7[a]	44.2	2.78E+06	2.78E+05	1.23E+07	4.02E+00
Area 8	126.0	1.71E+06	2.57E+05	3.23E+07	1.64E+01
	Totals	6.18E+06	7.81E+05	5.76E+07	8.27E+00

a. Areas 6A and 7A are included within Area 6 and Area 7, respectively.

Note: Mass calculations used the standard soil density of 1.5 g/cm^3 for INEEL soil for conversion from volume.

When the other areas to be remediated are included, the average concentration is reduced. The approach is similar to that used for those areas that have basalt in the 10 ft range. As shown in Table 4, the volume of the soil that will be removed/replaced is calculated by multiplying the area by the excavation depth. The total volume of the area is calculated by multiplying the area by 10 ft. The volume of soil below the remediation depth is calculated by subtracting the volume of the soil removed/replaced from the total volume. To determine the amount of residual mercury, the greatest concentration sampled in the first depth not planned for remediation was multiplied by the mass of the unremediated soil as shown in Table 5.

All areas to be remediated are included in development of a total average concentration of mercury in the soil in Table 6. The last line of this table presents the total mass of mercury divided by the total mass of clean soil and the total mass of soil containing residual contamination. The average mercury concentration for the whole pond area is calculated to be 2.9 mg/kg (Table 4). For comparison, the average mercury concentration within the remediated pond without the addition of fill soil was also calculated. As shown in Table 7, the average mercury concentration for the whole pond area without fill is calculated to be 3.94 mg/kg.

Table 4. Excavation depth, volume, and mass of remediated and unremediated soils for selected areas.

	Excavation Depth (ft)	Area (ft^2)	Total Volume to 10 ft Depth (cm^3)[a]	Volume of Soil Removed/Replaced (cm^3)	Volume of Soil Below Remediation Depth (cm^3)	Mass of Clean Soil (kg)	Mass of Soil Below Remediation Depth (kg)
Area 2	1	9.47E+03	2.68E+09	2.68E+08	2.41E+09	4.02E+05	3.62E+06
Area 2A	0.5	5.61E+04	1.59E+10	7.94E+08	1.51E+10	1.19E+06	2.26E+07
Area 11	3	2.05E+04	5.81E+09	1.74E+09	4.07E+09	2.62E+06	6.10E+06
Area 12	2	3.25E+03	9.19E+08	1.84E+08	7.36E+08	2.76E+05	1.10E+06
Area 13	2	5.64E+03	1.60E+09	3.20E+08	1.28E+09	4.79E+05	1.92E+06
Area 14	5	9.47E+03	2.68E+09	1.34E+09	1.34E+09	2.01E+06	2.01E+06

a. Conversion from cubic feet to cubic centimeter is done by multiplying by 28,316.85.

Table 5. Masses and concentrations used to estimate the average concentration of mercury in the soil.

	Concentration of Mercury (mg/kg) (Table 1)	Mass of Clean Soil (kg)	Mass of Soil Below Remediation Depth (kg)	Mass of Mercury (mg)	Average Concentration of Mercury in Soil (mg/kg)
Area 2	2.4	4.02E+05	3.62E+06	8.69E+06	2.16E+00
Area 2A	2.4	1.19E+06	2.26E+07	5.43E+07	2.28E+00
Area 11	2.2	2.62E+06	6.10E+06	1.34E+07	1.54E+00
Area 12	2.2	2.76E+05	1.10E+06	2.43E+06	1.76E+00
Area 13	2.0	4.79E+05	1.92E+06	3.84E+06	1.60E+00
Area 14	5.1	2.01E+06	2.01E+06	1.03E+07	2.55E+00

Table 6. Development of an average mercury concentration in soil, including all areas to be remediated at the pond.

	Mass of Clean Soil (kg)	Mass of Contaminated Soil (kg)	Mass of Mercury (mg)	Average Concentration of Mercury in Soil (mg/kg)
Area 2	4.02E+05	3.62E+06	8.89E+06	2.16E+00
Area 2A	1.19E+06	2.26E+07	5.43E+07	2.28E+00
Area 5	1.60E+05	1.44E+05	8.14E+06	2.67E+01
Area 6[a]	1.53E+06	1.02E+05	4.80E+06	2.94E+00
Area 7[a]	2.78E+06	2.78E+05	1.23E+07	4.02E+00
Area 8	1.71E+06	2.57E+05	3.23E+07	1.64E+01
Area 11	2.62E+06	6.10E+06	1.34E+07	1.54E+00
Area 12	2.76E+05	1.10E+06	2.43E+06	1.76E+00
Area 13	4.79E+05	1.92E+06	3.84E+06	1.60E+00
Area 14	2.01E+06	2.01E+06	1.03E+07	2.55E+00
Total Area	1.32E+07	3.82E+07	1.51E+08	2.93E+00

a. Areas 6A and 7A are included within Area 6 and Area 7, respectively.

Table 7. Development of an average mercury concentration in soil, including all areas to be remediated at the pond, without the addition of clean fill soil.

	Mass of Clean Soil (kg)	Mass of Contaminated Soil (kg)	Mass of Mercury (mg)	Average concentration of Mercury in Soil (mg/kg)
Area 2	0.00E+00	3.62E+06	8.69E+06	2.40E+00
Area 2A	0.00E+00	2.26E+07	5.43E+07	2.40E+00
Area 5	0.00E+00	1.44E+05	8.14E+06	5.64E+01
Area 6[a]	0.00E+00	1.02E+05	4.80E+06	4.70E+01
Area 7[a]	0.00E+00	2.78E+05	1.23E+07	4.42E+01
Area 8	0.00E+00	2.57E+05	3.23E+07	1.26E+02
Area 11	0.00E+00	6.10E+06	1.34E+07	2.20E+00
Area 12	0.00E+00	1.10E+06	2.43E+06	2.20E+00
Area 13	0.00E+00	1.92E+06	3.84E+06	2.00E+00
Area 14	0.00E+00	2.01E+06	1.03E+07	5.10E+00
Total Area	0.00E+00	3.82E+07	1.51E+08	3.94E+00

a. Areas 6A and 7A are included within Areas 6 and 7, respectively.

The FRG for the CFA-04 pond is 8.4 mg/kg. The FRG was calculated based on an area-weighted average or the area of the site as a whole. For this reason, similar comparisons can be made between the residual mercury contamination remaining in the CFA-04 pond across the site at 2.9 mg/kg and the FRG of 8.4 mg/kg. Residual mercury contamination following remedial activities, including contaminated soil/sediment remaining in basalt fractures, should fall below the FRG for human health. Postremediation sampling will be needed to validate this conclusion.

5. EVALUATION FOR HUMAN HEALTH

The final mercury remediation goal for human health risk was calculated using standard human health risk calculations in a future residential scenario (INEEL 2002b). This scenario assumes that an individual, 100 years in the future, will build a home in the contaminated area with a 10-ft basement and farm the land for fresh produce. The contamination levels detected are assumed to be evenly distributed through the soil to a 10-ft depth across the site. The exposed individual is assumed to be subject to the contamination 24 hours a day, 350 days a year for 30 years.

The primary pathway of concern for exposure to mercury at the CFA-04 pond was ingestion of homegrown produce (INEEL 2002b). This was driven by mercury contamination in both the groundwater and the soil. The homegrown exposure route includes an evaluation of mercury concentrations in plants caused by root uptake and irrigation with contaminated groundwater. The total source concentration evaluated in the homegrown produce ingestion exposure route is calculated by combining the exposure point concentration with the soil concentration that would result from equilibrium partitioning between soil and groundwater contaminated with mercury. This calculation is very conservative in that it does not take into account degradation, natural attenuation, and absorptive characteristics of the contaminant over time.

Groundwater concentrations resulting from surface and near-surface sources are estimated using the computer code GWSCREEN (Rood 1994). For each contaminant of potential concern (COPC), GWSCREEN produces groundwater concentrations versus time as the codes output. From this output, the maximum 30-year average groundwater concentration of each COPC and the 30-year average concentrations at 100 years in the future are calculated. The average concentrations at year 100 are used to calculate groundwater pathway risks for the residential exposure scenario, and the maximum average concentrations are used to calculate maximum expected groundwater risks.

The total mass of each contaminant, considered in the GWSCREEN modeling, is calculated by summing the contaminant masses from the retained site. The contaminant mass at the site is derived by multiplying the contaminant mean concentration (or maximum if the appropriate) by the mass of contaminated soil at the site. For example, if a contaminant has a mean concentration of 5 mg/kg at a release site with dimensions of 10 × 10 × 1 m (30 × 30 × 3 ft), the mass of the contaminant that would be used in the GWSCREEN modeling would be 7.7E+05 mg [(5 mg/kg/site) × (10 m) × (10 m) × (1 m) × (1E+06 cm^3/m^3) × (1.5 g/cm^3) × (1E–03 kg/g) = 7.7E+05 mg]. The total mass of mercury used in the GWSCREEN calculation for the CFA-04 pond FRG was 5.39E+08 mg.

Surface soil contamination also contributes to the risk for the ingestion of homegrown produce pathway (it is assumed that the contamination for homegrown produce is within the top 7 inches of the surface). Following remediation of the CFA-04 pond no mercury contamination will remain in the surface soil since all soil above the FRG will be removed from the site and replaced with clean soil. Therefore, surface soil concentrations of mercury will not contribute to homegrown produce uptake in a future residential scenario. Residual mercury contamination in soils above the FRG will only be present at depths within the basalt fractures.

In summary, if the total mass remaining after remediation is less than the mass used for the groundwater evaluation, and if the average soil concentration across the site is below the FRG, then the site is unlikely to pose any risk to human receptors. This will be verified with postremediation sampling and assessment.

6. EVALUATION FOR ECOLOGICAL RECEPTORS

The ecological risk assessment also uses a concentration calculated for the 10-ft depth range for assessment. Furthermore, the assessment uses the 95% UCL concentrations of the mean calculated as described in EPA *Guidance on Calculating Concentration Terms* (EPA 1992).

Based on the assessment in Section 4, the average concentration of residual mercury contamination potentially remaining in the soil, following the final remediation, will be below the FRG (Table 6). As shown in Table 3, only areas 5 and 8 within the pond will have concentrations above the FRG. The FRG is an average concentration across the site; therefore, it is acceptable that higher concentrations may be left in some locations (hot spots), mostly at depth. Small fractures within the basalt have limited use to most ecological receptors for habitat. Foraging exposure to ecological receptors is appropriately evaluated as an average.

As part of the long-term ecological monitoring plan (INEEL 2002c), plants and animals will be periodically evaluated in the CFA area. Mercury is a contaminant of concern at many sites and will be retained for evaluation across the INEEL. If elevated levels of mercury are detected in either the vegetation or animals at CFA, the CFA-04 pond will be included in any further assessment.

7. CONCLUSION AND DISCUSSION

The CFA-04 Pond will be remediated in fiscal year (FY) 2003. This remediation will include the excavation of the soil in areas 2, 5, 6, 7, 8, 11, 12, 13, and 14 (Figure 2). Areas 5 and 8 may contain levels of mercury in the soil within cracks of the basalt at levels above the FRG. At the time of excavation, all soil to the top of the basalt will be removed and a vacuum system will be used to collect all the soil possible from within all accessible cracks in the basalt.

The migration of mercury contamination through the soil column to groundwater is unlikely since the absorbency for mercury to soil is high (see discussion in Section 1.1.3). Therefore migration or transport of residual contamination is considered to be minimal. To date, groundwater monitoring at the CFA downgradient wells of CFA-MON-A-001, 002, and 003 as well as USGS-OBS-A-127 have not detected any mercury using a detection limit of 0.1 ug/liter (the MCL is 2 ug/L). Nitrate found in these three wells has been isotopically evaluated and determined to be linked to a different source (see discussion in Section 1.1.3). Groundwater monitoring will continue at the wells in the CFA area.

This evaluation has shown that the average mercury concentration in the soil (based on preremediation sampling) is comparable to the FRG developed for mercury cleanup at the CFA-04 pond. The average concentration of residual mercury estimated to remain within the pond is 2.9 mg/kg while the FRG for the CFA-04 pond is 8.4 mg/kg. The FRG was calculated based on an area-weighted average or the area of the site as a whole (INEEL 2002b). The residual mercury contamination was calculated based on those areas to be remediated in the CFA-04 pond. Therefore, the estimated residual mercury contamination was averaged across a smaller area, making it more conservative.

If the postremediation sampling indicates lower concentrations of mercury than assessed using the preremediation sampling, and if the soil to basalt ratio is 10% or less, then it should be acceptable to close this site as it does not appear to pose unacceptable risk to human or ecological receptors. In this situation institutional controls would not be necessary. Based on the uncertainties associated with the current knowledge of the pond and underlying basalt, postremediation sampling will be needed in order to validate assumptions made in this assessment and for final disposition of the site. If postremediation sampling indicates higher concentrations than assessed using the preremediation sampling, or if the soil to basalt ratio is greater than 10%, then it is possible to use this approach to evaluate the average concentration of residual mercury remaining at the pond to determine whether institutional controls will be required at the CFA-04 pond.

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